Use of modern technologies in estimating unaccounted water uses in the Murray-Darling Basin, Australia

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INTRODUCTION

The Murray-Darling Basin (M-DB) (Fig. 1) spreads over 1 million km^2 across five states: New South Wales, Victoria, Queensland, South Australia and the Australian Capital Territory, and is the food bowl of Australia. Although M-DB is only 14% of the land size of Australia, 70% of irrigation occurs here, and it is a major contributor to the Australian economy, accounting for more than 40% of national agricultural produce (M-DB Commission, MDBC, 2005). Agreed in 1995, the Cap (upper limit) on surface water diversions is central to the water management in M-DB. It is seen as an essential first step in establishing management systems to achieve healthy rivers and sustainable water use. The Cap will be replaced by sustainable diversion limits (SDL) on surface and groundwater under the proposed Basin Plan (M-DB Authority, MDBA, 2009).

Fig. 1 Murray-Darling Basin.

THE PROBLEM

All types of diversions, including those from flood plains and overland flows (named land surface diversions, LSD, to distinguish them from in-stream diversions) are included in the Cap (MDBA, 2010). Typically, in northern M-DB valleys, on-farm storages are used to store water from multiple sources (streams, LSD, groundwater). The same storage and distribution infrastructure (pumps, pipelines and channels) used for both taking and using water. This renders water measurement and accounting a wicked problem. Currently no reliable method exists to estimate LSD with any reasonable accuracy. Consequently, LSDs that form up to 30% of total surface diversions in some northern M-DB valleys (Bewsher, 2006) are not currently accounted for under the Cap. Thus the integrity of the Cap is undermined. The MDBA is committed to bringing LSD within the Cap (and the proposed SDL).

THE SOLUTION

Working out water balances on an individual property scale seems the only feasible solution to estimating LSD. Two complementary projects – a remote sensing project and an on-ground monitoring project – are currently underway for developing a method for estimating land surface diversions. The remote sensing project using satellite imagery analysis and geographical information system (GIS) techniques, has endeavoured to develop farm water balance models and used the data collected and analysed by the On-ground Monitoring project to validate those models. Charles Sturt University's (CSU) SAM-ET (Spatial Algorithm for Mapping actual Evapo-transpiration) model (Hafeez *et al.*, 2009) was used to estimate actual ET on six experimental farms, which were heavily instrumented including installation of automatic weather stations for tracking water movements and collecting meteorological data. A simplified conceptual model of an irrigated farm (Fig. 2) is described by:

$$\mathrm{KID} + \mathrm{LSD} + \mathrm{R} \geq \mathrm{ET_a} + \Delta S$$

Or, $\mathrm{LSD} \geq \mathrm{ET_a} - \mathrm{KID} - \mathrm{R} + \Delta S$

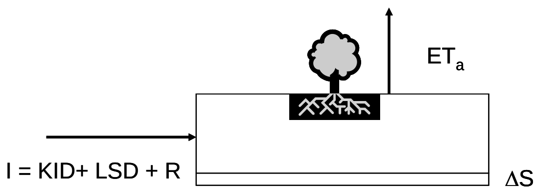

Fig. 2 Conceptual model.

where I is total irrigation, KID is known irrigation diversion from surface and groundwater sources, R is effective rainfall, $\mathrm{ET_a}$ is actual ET, and ΔS is change in storage, comprising changes in groundwater, surface water and soil moisture storages. Neglecting ΔS, the lower bound of LSD could be estimated. It may be reasonable to assume that long-term change in storage terms is negligible. While a reasonable long-term estimate of LSD could be obtained by neglecting ΔS, this assumption is problematic on an annual basis, where change in storage (e.g. farm storage volume) is quite large. It is possible to estimate change in on-farm storage volumes by estimating changes in surface area from satellite imagery combined with a fine resolution, digital terrain model. However, due to the almost vertical walls of on-farm storages, very little change in surface area causes large change in volumes, rendering this method ineffective. Without an accurate estimate of change in depth, change in on-farm storage volume is not possible to calculate.

Table 1 LSD estimates by the two methods.

Farm	LSD vol. ($\times 10^6$ m^3) Remote Sensing	On the ground
A	413	442
B	92	66
C	309	282
D	266	195
E	61	27
F	354	0

LSD volumes estimated by the remote sensing method (CSU, 2010) were comparable to the on-ground measurement estimate on four of six farms for the last irrigation season analysed (Table 1) when supplemented with estimate of on-farm losses. However, using remote sensing alone, LSD could not be worked out reliably.

Translating the on-farm LSD estimates to catchment scale is challenging. Two approaches are: Top-down – estimating ET_a and working out LSD through the water balance on a catchment scale; and Bottom-up – estimating ET_a, working out LSD through the water balance on local irrigated areas and summing them up to get LSD on a catchment scale. The former approach gave LSD estimates that were out by an order of magnitude. Such an approach is also not very useful from a water management perspective, as individual farmers and the local water managers need to know LSD volume on individual farms. The second approach requires a good estimate of irrigated area. Unlike intensively irrigated Asian and European countryside, irrigated areas, especially in northern M-DB, are patchy. Irrigation areas were identified through a comprehensive search logic that used a combination of variables, Normalised Deviation Vegetation Index, slope and temperature (CSU, 2010). LSD estimated through this approach looked reasonable. However, considerable uncertainty remains due to lack of proper accounting for storage terms. Unlike the six study farms, independent verification of catchment scale LSD estimate is not possible.

THE WAY FORWARD

Significant progress has been made on estimating unaccounted water diversions such as LSD. Models have been developed to estimate land surface diversions using on-ground measurements and remotely sensed data. The preliminary results are quite promising. However, significant further developments are required to validate these models in order to gain community confidence for being able to use them as regulatory tools. These include improvements necessary to incorporate various components of storage terms, which are not determinable by remote sensing. A bottom-up approach is preferable to a top-down approach to closing the water balance at the catchment scale. This requires accurate identification of irrigation areas. It seems that remote sensing coupled with some on-ground measurements is the way forward to reliably estimating unaccounted water diversions. The ultimate challenge is how to convert an experimental model to a cost effective operational tool that could be routinely used by water managers without being overwhelmed by the complexities involved. Learning experiences from other basins and countries are welcome.

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